DEFOLIATION EFFECTS ON PLANT PRODUCTION, VIGOR, AND CARBOHYDRATE RESERVE STATUS FOR SEVERAL IMPORTANT COLORADO RANGE SPECIES.

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Dr. David Wilson
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Denver Service Center, Bldg. 50
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Dear Dr. Wilson:

Enclosed is your copy of the annual report for the BLM-CSU research project "Photosynthesis and Carbohydrate Budget in Range Plants with Respect to Phenological Development and Defoliation." We initiated this project July 1, 1970 and feel that we have made good progress to date. Dr. John Menke has finished his Ph.D. dissertation on this project, and you should have received a copy of his dissertation. We presently have two graduate students working on various phases of the project. Mr. Malami Buwai is presently working in the field on plant production, vigor and carbohydrate reserves as related to frequency and intensity of defoliation while Mr. Ned Fetcher is working on the model of plant vigor and carbohydrate reserves as related to grazing systems.

If we can be of any assistance, please do not hesitate to contact us.

Sincerely yours,

Joe Trlica

M. J. Trlica
Assistant Professor

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Defoliation Effects on Plant Production, Vigor, and Carbohydrate Reserve Status for Several Important Colorado Range Species

A progress report
submitted to the
Bureau of Land Management

by

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INTRODUCTION

The multiple use of rangelands for livestock production, wildlife habitat and recreation requires a great deal of understanding of the ecological factors that influence the structure and function of ecosystems. The range manager should understand how management decisions affect the welfare of the plant species that protect the soil and provide food and cover for wildlife and livestock. The achievement of sustained benefits without damaging the ecosystem can only be realized through adequate research on the structure and function of these ecosystems. Research data provides a guide to the manager on how to achieve sustained yield without permanent damage to the vegetation resource. Management systems should include a consideration of how grazing systems affect the vegetation. Plant species react differently to different biotic and abiotic factors within the ecosystem. Therefore, the effects of forage utilization on the welfare of the key species must be understood in order to properly manage rangelands.

Several studies have shown that forage utilization affecting the welfare of plant species can be evaluated though data obtained for herbage yield, vigor and carbohydrate reserve levels. Carbohydrate reserves result from surplus food which has been acquired through photosynthesis and accumulated to meet future demands. Roots and crowns are usually the most important storage organs in many range plants. However, rhizomes, stolons, tubers and basal stems may also serve as storage organs in many plant species. The importance of a storage organ varies with the species. The extent of the effects of defoliations on plant species is influenced by frequency, intensity and time of defoliation. The association with other species and site characteristics will also influence the extent of damage done to a plant species as a result of herbage removal.

In 1970 Colorado State University in cooperation with the Bureau of Land Management began a study on the effects of defoliation systems on the welfare of important range species. This progress report will deal with the effects of defoliations on herbage yield, vigor and carbohydrate reserve levels of some important Colorado range species.

OBJECTIVES:

This study was undertaken to provide information on herbage yield, vigor and root or basal stem carbohydrate reserves of several important range species as influenced by several defoliation treatments. The objectives of this phase of the study are:

1. To determine the level of utilization that will maintain optimum herbage yield, vigor and carbohydrate reserves.
2. To determine the effects of multiple defoliations at various phenological stages on herbage yield, vigor and carbohydrate reserves.
3. To determine if defoliation for two consecutive years is more detrimental to plant welfare than defoliation for only one year.
4. To determine recovery of herbage yield, vigor and carbohydrate reserves for defoliated plants after one and two years of rest.

PROCEDURE:

1. One-year Multiple Defoliations

This section of the study was initiated to determine the effect of multiple defoliations on herbage yield, vigor, and carbohydrate reserves of five plant species. The current photosynthetic tissues of these species were clipped at two intensities; heavy (90% of the foliage was removed), and moderate (60% of the foliage was removed). Plants from these two

treatments were compared with unclipped control plants.

The following species were included in the experiment: blue grama *(Bouteloua gracilis)*, western wheatgrass *(Agropyron smithii)*, antelope bitterbrush *(Purshia tridentata)*, fourwing saltbush *(Atriplex canescens)*, and fringed sagewort *(Artemisia frigida)*. Exclosures including the above species were built in December 1972 at the Pawnee site. However, because of early snow accumulation at Maybell in 1972, selection of study sites and exclosure construction was delayed until May 1973. Thus, antelope bitterbrush and fringed sagewort included within exclosures at the Maybell location were not studied until 1973. Clipping treatments on these two species were begun in the fall of 1973. There were three exclosure sites utilized at each of the two locations.

Four replications per exclosure site per intensity were used for all species except fringed sagewort, where eight replications were necessary to insure adequate sampling. A replication was defined for the browse species, antelope bitterbrush and fourwing saltbush and for fringed sagewort as the number of individual plants included in a clipping treatment per intensity at each site. For the two grasses, a replication was defined as a $0.224m^2$ plot.

All vigor measurements for all of the species were made for each replication. Actual herbage yield for the grasses and fringed sagewort was obtained on all the replications at each site; whereas, a double sampling technique was used to obtain herbage yield for antelope bitterbrush and fourwing saltbush. Actual herbage yield for two browse plants per site were obtained, while herbage yield of the other two plants were estimated. This will allow these species to be included in a later study which will examine recovery of defoliated plants after a rest period.

Data for vigor, herbage yield, and carbohydrate reserve levels were obtained in the fall of 1973 after plants had been either defoliated twice or three times during 1972 and 1973. Herbage samples were oven dried at 70°C for a 24-hour period. Roots (blue grama, western wheatgrass and fringed sagewort) or basal stems (antelope bitterbrush and fourwing saltbush) were washed with water, covered with 95% ethanol to reduce enzyme activity, dried at 70°C and ground to pass through a 40-mesh screen. Carbohydrate reserve levels were determined using standard laboratory analysis procedure and reported in mg/g. Six replications of each treatment and each clipping intensity were used for carbohydrate determinations for all species.

Plant vigor category was estimated and categorized by assigning numbers as follows:

1 = very high vigor

2 = high vigor

3 = medium vigor

4 = low vigor

5 = very low vigor

The plant vigor category integrated other vigor measurements into a single number. In other words, plants with a high number of seed stalks, basal cover, production, etc. would be rated as having very high vigor (1). If some of these vigor measurements were low, a lower vigor category would be given.

2. <u>Two-year Multiple Defoliations</u>

Only four species were included in this portion of the study. Of the five species mentioned previously, only fringed sagewort was not included in this portion of the study. The study was initiated in the fall of 1972

at the Pawnee location and in the spring of 1972 at the Maybell location. Plants were subjected to multiple defoliations at 60% or 90% intensity at different phenological stages during a two-year period. The effect of these multiple defoliations on herbage yield, vigor and carbohydrate reserve levels will be evaluated in the fall of 1974.

3. Recovery of Defoliated Plants

This portion of the study dealt with the recovery of plants that were subjected to a single or to multiple defoliations at 90% intensity of foliage removal during various phenological stages. Single defoliations were made during 1971 and 1972; whereas, multiple defoliations were made from 1970 through 1972. The effects of the defoliations were evaluated in the fall of 1973 after plants had at least 14 months of rest from a single defoliation treatment and at least two years of rest from the multiple defoliation treatments.

In addition to the five species mentioned previously, two additional species, little rabbitbrush *(Chrysothamus vicidiflorus)* and scarlet globemallow *(Sphaeralcea coccinea)* were included in this portion of the study. Three plants per exclosure site were clipped under each treatment for fourwing saltbush, antelope bitterbrush, and little rabbitbrush. Eight plants per exclosure site were clipped for each treatment for fringed sagewort. Plants within $1.0m^2$ to $1.5m^2$ plots were clipped at each exclosure site at the Pawnee location for blue grama, western wheatgrass and scarlet globemallow.

Herbage yield for blue grama was adjusted to 100% basal cover per $1.0m^2$. For all the other species studied, herbage yield was reported as grams per plant. Herbage yield and vigor for antelope bitterbrush, fourwing saltbush and little rabbitbrush were obtained only from an average

plant. Herbage yield and vigor measurements for western wheatgrass and globemallow were obtained from 80 and 40 plant samples, respectively. All eight plants were used to determine herbage yield and vigor of fringed sagewort. Control plants were used to standardize herbage yield of shrubs and half-shrubs.

Only one sample at each exclosure site for each treatment and species was used to determine carbohydrate reserve level. Therefore, carbohydrate reserve values were determined for three replications of each treatment for each of the species. The carbohydrate reserve results are reported in mg per g of sample.

RESULTS AND DISCUSSION:

A. The effects of multiple defoliations on herbage yield, vigor, and carbohydrate reserves of range plants.

Three species, blue grama, western wheatgrass and fourwing saltbush were defoliated at moderate and heavy intensities at different phenological stages during 1972 and 1973. The effects of the defoliations were evaluated in the fall of 1973.

Western wheatgrass:

It was observed that all clipping treatments reduced vigor (as indicated by five plant characteristics) and herbage yield below that of the control plants (Table 1). However, heavy clipping reduced vigor and herbage yield more than did moderate clipping under all clipping treatments (Table 1).

All clipping treatments lowered basal cover below that of the control plants, but moderate defoliation at quiescence and rapid growth (clipping

Table 1. Average herbage yield, vigor, and root carbohydrate reserve levels for western wheatgrass *(Agropyron smithii)* subjected to multiple defoliations during various phenological stages and at two intensities during 1972-1973. Measurements and collections were made in the fall of 1973.

Treatment Number	Phenological stage when defoliated	Intensity of foliage removal	Vigor: Basal cover (%)	Vigor: Number of seedstalks per m^2	Vigor: Seedstalk length (cm)	Vigor: Plant height (cm)	Vigor: Plant vigor category	Herbage yield (g/m^2)	Carbohydrate reserve level (mg/g)
1	Control (not defoliated)	none	16.7	83.1	43.6	27.3	1.4	203.8	161.8
2	Quiescence and Rapid growth	moderate	12.5	64.3	42.6	23.8	2.2	158.2	163.2
		heavy	9.6	17.0	38.8	22.1	3.1	123.8	200.6
3	Rapid growth and Seedset	moderate	10.8	0.0	0.0	19.5	3.1	107.2	186.1
		heavy	6.5	0.0	0.0	14.9	4.0	41.1	170.2
4	Quiescence, and Seedset	moderate	9.2	0.0	0.0	18.6	3.4	60.3	162.1
		heavy	4.3	0.0	0.0	16.9	4.2	21.0	164.3
5	Quiescence, Rapid growth, and Seedset	moderate	8.7	0.0	0.0	16.9	4.1	48.3	201.5
		heavy	4.3	0.0	0.0	13.8	4.4	19.2	166.8

treatment 2) resulted in higher basal cover than among other clipping treatments. Basal cover was always higher with moderate clipping than with heavy clipping under all clipping treatments. Moderate defoliation during quiescence, rapid growth and seedset (clipping treatment 5) reduced the basal cover of western wheatgrass below that obtained with a similar intensity of clipping in treatments 2, 3, and 4 or heavy defoliation in clipping treatment 2 (Table 1). The basal cover of western wheatgrass plants was greatly reduced by heavy defoliations in clipping treatments 4 and 5.

Defoliation during seedset (clipping treatments 3, 4, and 5) resulted in plants of shorter stature and no seedstalks being produced under both the moderate and heavy defoliations. Moderate defoliation during quiescence and rapid growth slightly reduced the number and length of seedstalks below those of the control plants. Heavy defoliation during the same period (clipping treatment 2) greatly reduced the number and length of seedstalks below those of the control. All clipping treatments reduced plant height below the control. However, the clipping effect was less pronounced if done during quiescence and rapid growth at both intensities than at other phenological stages (Table 1).

Plant vigor was highest for control plants (Table 1). Plants that were defoliated at a moderate intensity during quiescence and rapid growth had the next highest vigor rating among clipped plants. Plant vigor was the same between heavy defoliation in clipping treatment 2 and moderate defoliation in clipping treatment 3. Heavy defoliations in clipping treatment 3 and 4 resulted in about the same plant vigor as with moderate defoliation in clipping treatment 5. Heavy defoliation in clipping treatment 5 resulted in the lowest plant vigor value.

Defoliation at either heavy or moderate intensities reduced herbage yield of western wheatgrass below that of the control (Table 1). Moderate defoliations resulted in higher herbage yields than heavy defoliations during the same phenological stages. Moderate and heavy defoliations during quiescence and rapid growth resulted in higher herbage yield than under any other clipping treatment. Moderate defoliation in clipping treatment 3 resulted in higher herbage yield than a similar clipping intensity in clipping treatment 4 and 5. Herbage yield was reduced the most by heavy defoliations in clipping treatment 4 and 5 (Table 1).

Multiple defoliations of western wheatgrass appeared to have only a small influence on carbohydrate reserve storage. All clipped plants had slightly higher carbohydrate reserve levels than did the control plants at fall quiescence (Table 1). Moderate defoliations during either rapid growth and seedset or during quiescence, rapid growth and seedset, caused largest reserve increases. Heavy defoliation during quiescence and rapid growth also resulted in very high root carbohydrate reserve levels. Moderate defoliations during either quiescence and rapid growth or during quiescence and seedset resulted in a small increase in carbohydrate reserve level compared with unclipped plants (Table 1).

Blue grama:

All clipping treatments lowered the vigor, herbage yield and root carbohydrate reserve levels of blue grama (Table 2). The effects of defoliation however, were less detrimental when done during quiescence and rapid growth. Moderate defoliation resulted in greater basal cover, taller plants, more seedstalks and longer seedstalks than heavy defoliation under any clipping treatment (Table 2). Moderate defoliation during quiescence and rapid growth resulted in greater basal cover, more and

Table 2. Average herbage yield, vigor, and root carbohydrate reserve levels for blue grama (*Bouteloua gracilis*) defoliated under three clipping schedules and at two intensities during 1972-1973. Measurements and collections were made during the fall of 1973.

			Vigor						
Treatment number	Phenological stage when defoliated	Intensity of foliage removal	Basal cover (%)	Number of seedstalks per m^2	Seedstalk length (cm)	Plant height (cm)	Plant vigor category	Herbage yield (g/m^2)	Carbohydrate reserve level (mg/g)
1	Control	none	27.7	267.2	34.1	8.7	1.0	135.9	58.4
2	Quiescence and rapid growth	moderate	22.5	154.6	28.4	7.0	2.0	83.1	55.9
		heavy	17.9	116.6	22.0	4.8	2.7	47.4	53.7
3	Rapid growth and seedset	moderate	21.3	10.3	27.9	4.1	3.0	45.6	48.1
		heavy	19.2	0.0	0.0	3.2	4.3	17.0	55.9
4	Quiescence and seedset	moderate	22.1	18.8	24.0	4.3	3.0	56.3	52.0
		heavy	17.1	0.0	0.0	3.3	4.3	28.2	51.9

longer seedstalks, and taller plants than any other use under the other two clipping treatments.

The differences in basal cover for moderate defoliations were small among all three clipping treatments. Heavy defoliation resulted in fairly similar basal cover values among all three clipping treatments.

Defoliations during seedset, clipping treatments 3 and 4, greatly reduced the number and length of seedstalks and plant height. The difference in seedstalks length between moderate clipping at quiescence and rapid growth and moderate clipping at rapid growth and seedset was small. Plant height was fairly similar among heavy defoliations in clipping treatment 2 and moderate defoliations in clipping treatments 3 and 4 (Table 2). The shortest plants were found under heavy defoliations during both rapid growth and seedset and quiescence and seedset (clipping treatments 3 and 4). Moderate defoliation during quiescence and rapid growth resulted in taller plants than found under any other clipping treatment.

Plant vigor was reduced by all clipping treatments (Table 2). However, plant vigor was higher under clipping treatment 2 than under any of the other clipping treatments. Heavy defoliations in clipping treatments 3 and 4 greatly reduced overall plant vigor of blue grama.

Herbage yield of blue grama was reduced by all three clipping treatments (Table 2). Moderate defoliation resulted in about twice as much herbage remaining at the end of the growing season as under heavy defoliation during the same phenological stages. Herbage yield was most affected by heavy defoliation during rapid growth and seedset. Heavy defoliation during quiescence and rapid growth resulted in about the same herbage yield as under moderate defoliation during rapid growth and seedset.

All clipping treatments reduced root carbohydrate reserve levels but

the differences between clipped and unclipped plants were not great. The differences in carbohydrate reserve levels among moderately clipped plants and heavily clipped plants were small, except in clipping treatment 3 (Table 2). Moderate defoliation usually resulted in slightly higher carbohydrate reserve levels than under heavy defoliations, except in clipping treatment 3 where moderately clipped plants had lower root carbohydrate reserve levels.

Fourwing saltbush:

The effect of clipping treatments on herbage yield, vigor and basal stem carbohydrate reserve levels for fourwing saltbush are shown in Table 3. Multiple defoliations reduced live crown cover, number of seedstalks, twig length, seedstalk length (or twig length), plant height and live crown diameter under all clipping treatments. Vigor measurements were highest in unclipped plants and lowest in heavily defoliated plants. Live crown cover, number of seedstalks and seedstalk length (or twig length) were greatly affected by intensity of defoliation and time of defoliation. Moderately clipped plants in clipping treatment 2 had greater live crown cover and were taller than moderately clipped plants in clipping treatment 3 and 4. Moderate defoliation during quiescence and seedset resulted in longer seedstalks than when plants were moderately defoliated in either clipping treatments 2 or 3.

All clipping treatments caused plants to be placed in a low vigor category, with heavily defoliated plants having the lowest vigor. Moderate defoliations resulted in plants being placed into fairly similar plant vigor categories.

Herbage yield was greatly influenced by intensity and time of

Table 3. Average herbage yield, vigor, and basal stem carbohydrate reserve levels for fourwing saltbush (*Atriplex canescens*) defoliated under three clipping schedules and at two intensities during 1972-1973. Measurements and collections were made during the fall of 1973.

Treatment number	Phenological stage when defoliated	Intensity of foliage removal	Vigor: Live crown cover (%)	Vigor: Number of seedstalks per plant	Vigor: Seedstalk length (cm)	Vigor: Plant height (cm)	Vigor: Live crown diameter (cm)	Vigor: Plant vigor category	Herbage Yield: Dry wt. of leaves and seeds (g/plant)	Herbage Yield: Dry wt. of current years twig (g/plant)	Carbohydrate reserve level (mg/g)
1	Control (not defoliated)	none	72.3	72.3	14.5	58.3	87.3	1.5	104.4	107.3	44.8
2	Quiescence and rapid growth	moderate	52.5	6.3	13.9	50.4	67.5	3.2	31.9	41.4	46.8
		heavy	39.6	1.3	12.3	48.3	66.7	4.4	21.2	45.9	40.1
3	Rapid growth and seedset	moderate	51.3	14.6	9.7	45.2	74.6	3.3	43.2	35.9	44.3
		heavy	39.2	0.0	8.7	45.8	70.5	4.3	16.3	17.4	36.6
4	Quiescence and seedset	moderate	45.8	11.4	14.3	43.8	67.1	3.3	26.6	29.6	40.2
		heavy	36.0	0.0	5.8	43.9	65.2	4.8	13.0	14.4	33.4

defoliations. All clipping treatments greatly reduced herbage yield at fall quiescence. The dry weight of leaves and seeds was greater with moderate defoliation than with heavy defoliation. Moderately clipped plants in clipping treatment 3 had higher dry weight of leaves and seeds than plants in other clipping treatments (Table 3). Heavily defoliated plants in clipping treatment 4 had the lowest herbage yield both in dry weight of leaves and seeds and in dry weight of current year's twigs. Moderate defoliations during quiescence and seedset (clipping treatment 4) also caused lower herbage yield than with a similar intensity of clipping in treatments 2 and 3. The dry weight of twigs was less affected by defoliation during quiescence and rapid growth (treatment 2) than defoliation in either rapid growth and seedset (treatment 3) or quiescence and seedset (treatment 4). Total herbage yield was most affected by clipping treatment 4.

Most clipping treatments resulted in low carbohydrate reserve levels in the basal stems of fourwing saltbush (Table 3). The differences in carbohydrate reserve levels among unclipped plants and moderate clipped plants (clipping treatments 2, 3, and 4) were however, small. Carbohydrate reserve levels were most affected when plants were heavily defoliated during either rapid growth and seedset or during quiescence and seedset.

B. Recovery of defoliated plants after one and two years rest.

In this portion of the study the recovery of defoliated plants after a period of rest was determined. All species included in this phase of the study received either a single defoliation or multiple defoliations at 90% foliage removal and were then given a period of rest (14 to 24 months) before data on herbage yield, vigor and carbohydrate reserves were obtain-

ed. The treated plants were compared with unclipped plants to determine the effects of clipping treatments and rest periods.

The single defoliation treatments were repeated in two separate experiments. Plants were given a single defoliation during 1970 or 1971 and then evaluated in the fall of 1972. A similar experiment was repeated in 1971 or 1972 using the same phenological stages for clipping. Treated plants were then evaluated in the fall of 1973.

The multiple defoliation treatments were done only during 1970 and 1971. However enough samples were included within each clipping treatment to ensure that recovery from clipping effects could be evaluated after one and two years of rest.

1. Single defoliation treatments

Fourwing saltbush:

The recovery of defoliated fourwing saltbush plants after rest is shown in Table 4. The effects of a single defoliation on plant vigor were still evident even though defoliated plants had received a 14 to 24 month period of rest.

The effects of clipping treatments on the seedstalk length was more severe in the first year of the study than in the second year. It was observed that defoliation at quiescence had little effect on seedstalk length, whereas seedstalk length was greatly reduced when plants were defoliated at near maturity. Clipping at either early growth or rapid growth only moderately affected the seedstalk length when plants received a period of rest during both years of the study.

In 1972, previous clipping at the near maturity stage greatly reduced the live crown cover. However, all the clipping treatments and the control

Table 4. Average herbage yield, vigor and carbohydrate reserve levels in tap roots and basal stems of fourwing saltbush *(Atriplex canescences)* subjected to a single defoliation during various phenological stages (1970 through 1972). Measurements and collections were made in the fall of 1972 and 1973 after clipped plants had received period of rest.

Phenological stage when defoliated	Vigor: Seedstalk length(cm) 1972	Vigor: Seedstalk length(cm) 1973	Vigor: Live crown cover(%) 1972	Vigor: Live crown cover(%) 1973	Dry wt. of leaves and seeds per plant (g) 1972	Dry wt. of leaves and seeds per plant (g) 1973	Carbohydrate reserve levels (mg/g): Tap Roots 1972	Tap Roots 1973	Basal stems 1972	Basal stems 1973
Control	11.2	14.7	100.0	75.0	199.4	95.5	74.8	81.1	52.2	61.8
Quiescence	10.0	13.3	73.7	46.7	238.6	32.3	73.6	83.0	50.3	42.8
Early growth	9.8	12.3	70.0	55.0	123.6	50.1	65.6	70.0	52.6	51.3
Rapid growth	9.3	12.3	63.3	58.3	144.8	73.2	52.8	79.8	35.6	60.5
Near maturity	7.0	8.0	36.7	55.0	31.4	34.2	56.5	93.8	34.4	53.1

had lower live crown cover in 1973 than in 1972 (Table 4). A previous defoliation at quiescence affected live crown cover more than any other clipping treatment in 1973 (Table 4). If defoliation treatments in 1972 and 1973 were averaged however, live crown cover was most affected by defoliation at near maturity than at any other phenological stage. Clipping at either early growth or rapid growth only slightly affected live crown cover.

There was a large difference in the herbage yield obtained for both unclipped and clipped plants (except for plants that received defoliation at the near maturity stage) in the two separate years of the study (Table 4). Plants that were clipped at near maturity had about the same herbage yield in both years, but herbage yield in 1973 from the other clipping treatments and the control were less than half that obtained in 1972. Herbage yield was less affected by clipping at quiescence than clipping at the other phenological stages studied if data for the two years were averaged. Plants that received a single defoliation at near maturity made little recovery in herbage yield even after a period of rest.

In general, carbohydrate reserve levels were greater in 1973 than in 1972 in both the tap root and basal stems of clipped and unclipped plants (Table 4). Plants that were defoliated at the near maturity stage made significant recovery in tap root carbohydrate reserve levels in 1973, but made less recovery in the 1972 study. Tap root carbohydrate reserve levels were not affected by a quiescence clipping if followed by rest (Table 4). Those plants that were defoliated at quiescence had tap root carbohydrate reserve level comparable to the unclipped plants. However, quiescence clipping greatly reduced basal stem carbohydrate reserve levels in 1973 but had little effect on basal stem reserves of fourwing saltbush in 1972.

The near maturity clipping greatly reduced basal stem carbohydrate reserve levels in 1972, but only moderately reduced reserve levels in 1973. The effects of clipping on carbohydrate reserve levels of basal stems were pronounced when plants were defoliated at near maturity.

Antelope bitterbrush:

The effects of a single defoliation on the recovery of antelope bitterbrush twig length was most severe if defoliation was done at the fruit development stage in both years of the study (Table 5). Twig length after rest was little affected by clipping at quiescence, early growth, or seed-shatter. Twig length was longer in 1973 than in 1972 in both clipped and unclipped plants. In both years of the study, twigs were longer for plants that received either a quiescence or early growth defoliation than were twigs of the control plants.

There was little difference among clipping treatments in the estimated live crown cover in 1973, although all clipping treatments reduced live crown cover (Table 5). However, there were great differences among the clipping treatments in live crown cover in 1972. Plants from the quiescence and early growth clipping treatments had the highest live crown cover among the clipping treatments in 1972. Live crown cover was most severly affected by defoliation at the fruit development stage.

Herbage yield of antelope bitterbrush was fairly similar among the clipping treatments in 1972 and 1973, but there was a great difference in the yields of unclipped plants between the two years of the study (Table 5). Herbage yield after rest was less affected by a previous clipping at quiescence than clipping at other stages. The differences among herbage yields of clipped plants and control plants was greater in 1973 than in 1972. Thus if only 1972 data were considered, plants that were clipped at

Table 5. Average herbage yield, vigor and carbohydrate reserve levels in tap roots, and basal stems of antelope bitterbrush *(Purshia tridentata)* subjected to a single defoliation during various phenological stages (1970 through 1972). Measurements and collections were made in the fall of 1972 and 1973 after clipped plants had received a period of rest.

Phenological stage when defoliated	Vigor: Twig length (cm) 1972	Vigor: Twig length (cm) 1973	Vigor: Live crown cover (%) 1972	Vigor: Live crown cover (%) 1973	Dry wt. of leaves per plant (g) 1972	Dry wt. of leaves per plant (g) 1973	Carbohydrate Reserve Levels (mg/g): Tap Root 1972	Tap Root 1973	Basal stem 1972	Basal stem 1973
Control	9.3	14.7	100.0	100.0	38.2	74.8	76.3	64.0	67.3	69.2
Quiescence	12.0	17.7	88.3	46.7	35.5	44.4	64.9	62.4	54.1	52.1
Early growth	12.0	15.7	88.3	46.7	34.0	36.9	55.4	68.4	58.5	53.1
Fruit developing	8.7	12.3	46.7	46.7	31.8	32.5	67.5	50.3	49.8	49.0
Seed shatter	11.3	14.7	60.0	40.0	17.4	27.6	66.9	57.8	38.7	47.7

quiescence, early growth or fruit developing stages made significant recovery in herbage yield (Table 5). However, clipping at the seed shatter stage severely reduced herbage yield in both 1972 and 1973.

The differences in carbohydrate reserve levels between 1972 and 1973 was small. Plants of antelope bitterbrush from all clipping treatments still had lower carbohydrate reserve levels after rest than the unclipped plants in both storage organs examined and in both years of the study (Table 5). Tap root carbohydrate reserve levels were most affected by defoliations at early growth or at the fruit developing stage. However, basal stem carbohydrate reserve levels were severely reduced by defoliation at seed shatter in both years of the study.

Fringed Sagewort:

All clipping treatments greatly reduced herbage yield, vigor and carbohydrate reserves of fringed sagewort even after defoliated plants had received a period of rest (Table 6). In general, seedstalk length and live crown cover was somewhat greater in 1973 than in 1972. In 1972, seedstalk length had been most affected by clipping at quiescence. However, in 1973, seedstalks were the shortest when defoliation had occurred during rapid growth. Considering both years of the study, it appeared that defoliation at rapid growth severely reduced seedstalk length. It should be pointed out, however, that all defoliated plants had seedstalk lengths less than half those of unclipped plants.

Live crown cover was least affected by defoliation at early growth in the first year of the study and by defoliation at quiescence in the second year of the study. In both years of the study, defoliation at rapid growth was most detrimental to recovery of live crown cover. However, plants of

Table 6. Average herbage yield, vigor, and carbohydrate reserve levels in roots and crowns of fringed sagewort *(Artemisia frigida)* subjected to a single defoliation during various phenological stages (1970 through 1972). Measurements and collections were made in the fall of 1972 and 1973 after clipped plants had received a period of rest.

Phenological stage when developed	Vigor: Seedstalk length (cm)		Vigor: Live crown cover (%)		Aboveground dry wt. per plant (g)		Carbohydrate reserve levels (mg/g): Roots		Carbohydrate reserve levels (mg/g): Crowns	
	1972	1973	1972	1973	1972	1973	1972	1973	1972	1973
Control	21.0	22.7	70.0	76.7	5.4	4.2	109.5	141.0	42.6	57.3
Quiescence	2.3	11.7	2.3	26.7	1.7	1.8	18.4	76.7	17.0	26.9
Early growth	3.7	5.0	11.0	6.7	1.1	0.9	29.8	41.6	16.2	23.6
Rapid growth	3.0	2.3	0.0	5.3	1.0	0.3	15.4	21.4	14.7	33.7
Near maturity	3.2	4.3	7.3	16.7	1.6	1.3	26.1	68.8	16.6	22.7

fringed sagewort from all the clipping treatments had less than one-third the live crown cover of the unclipped plants (Table 6).

Herbage yield data was fairly similar for both years of the study, with yields being greatly reduced by all the clipping treatments. Herbage yield was, however, less affected by defoliation at quiescence than defoliations at any of the other phenological stages. Defoliations at rapid growth resulted in the greatest reductions in herbage yield after a period of rest.

The differences in fringed sagewort carbohydrate reserve levels between the two years of the study varied among the stages of defoliation (Table 6). There was little difference in either root or crown carbohydrate reserve levels among plants from the clipping treatments in 1972, but data from the 1973 study showed that defoliation at quiescence resulted in higher root carbohydrate reserve levels than for plants from the other clipping treatments. The average TAC levels for the two years of the study showed clipping at rapid growth greatly depressed root carbohydrate reserve levels.

Little rabbitbrush:

Recovery of little rabbitbrush from clipping treatments is shown in Table 7. It was observed that all clipped plants made good recovery in seedstalk length during both years of the study. Defoliations at either quiescence or flowers developing stages had the least effect on seedstalk length after a period of rest.

Live crown cover was less in 1973 than in 1972. Clipping at quiescence or flowers developing had little effect on live crown cover. However, when plants were defoliated at rapid growth, recovery of live crown

Table 7. Average herbage yield, vigor, and carbohydrate reserve levels in roots and crowns of little rabbitbrush *(Chrysothamnus vicidiflorus)* subjected to a single defoliation during various phenological stages (1970 through 1972). Measurements and collections were made in the fall of 1972 and 1973 after clipped plants had received a period of rest.

Phenological stages when defoliated	Vigor				Dry wt. of leaves per plant (g)		Carbohydrate reserve levels (mg/g)			
	Seedstalk length (cm)		Live crown cover (%)				Roots		Crowns	
	1972	1973	1972	1973	1972	1973	1972	1973	1972	1973
Control	11.7	19.3	60.0	60.0	8.6	25.8	103.7	103.0	74.4	84.5
Quiescence	12.7	18.0	66.7	48.3	7.6	21.9	88.7	77.1	68.7	87.8
Early growth	10.7	16.7	46.7	40.0	7.8	16.8	107.0	76.6	67.4	76.0
Rapid growth	13.0	15.7	28.3	28.3	7.7	5.0	78.1	59.0	63.0	37.8
Flowers developing	13.3	20.7	60.0	46.7	8.3	17.9	112.0	110.3	84.1	98.2

cover was severely limited during both years of the study.

Recovery of herbage yield was good within all clipping treatments in 1972, but was greatly reduced by several clipping treatments in the 1973 study (Table 7). Plants clipped at rapid growth had the lowest herbage yield among the clipping treatments when data were taken in 1973.

In general, root carbohydrate reserve levels were lower in 1973 than in 1972, with crowns reserve levels being somewhat higher in 1973 than in 1972 (Table 7). Defoliation resulted in a reduction in carbohydrate reserve levels below control plants even after a period of rest except when clipping was done at the flowers developing stage. Both root and crown carbohydrate reserve levels were higher after rest in plants that received a single defoliation at the flowers developing stage in both 1972 and 1973. Defoliation at the rapid growth stage greatly reduced carbohydrate reserve levels in both storage organs during both study years.

Scarlet globemallow:

The effects of clipping treatments on herbage yield and vigor of scarlet globemallow were still evident even after a period of rest (Table 8). Most defoliated plants made less fall regrowth, had lower herbage yields and were shorter than the unclipped plants in both study years. Defoliation at quiescence had less effect than defoliation at any other stage for both plant height and fall regrowth. In fact, the 1972 data showed fall regrowth to be highest for plants clipped at quiescence. Plant height was fairly similar among the early growth clipping treatment, rapid growth treatment, and near maturity treatment. Plants from the rapid growth clipping treatment had the lowest average fall regrowth (averaged for the two study years) among all the clipping treatments.

Table 8. Average herbage yield, vigor, and carbohydrate reserve levels in roots and crowns of scarlet globemallow *(Sphaeralcea coccinea)* subjected to a single defoliation during various phenological stages (1970 through 1972). Measurements and collections were made in the fall of 1972 and 1973 after clipped plants had received a period of rest.

Phenological stage when defoliated	Vigor: Plant height (cm) 1972	Vigor: Plant height (cm) 1973	Vigor: Fall regrowth (cm) 1972	Vigor: Fall regrowth (cm) 1973	Dry wt. per shoot (g) 1972	Dry wt. per shoot (g) 1973	Carbohydrate reserve levels (mg/g): Roots 1972	Roots 1973	Crowns 1972	Crowns 1973
Control	12.0	16.3	1.7	2.3	0.55	0.99	171.2	168.6	145.3	156.4
Quiescence	11.8	13.3	2.5	1.5	0.50	0.51	158.6	174.4	154.5	138.4
Early growth	9.5	10.3	1.7	1.3	0.25	0.52	172.9	161.2	142.8	135.1
Rapid growth	9.5	10.3	1.5	1.0	0.35	0.26	170.9	191.0	144.4	137.8
Near maturity	9.5	9.3	1.4	1.2	0.41	0.42	178.7	160.9	143.2	167.3

Herbage yield data between the two years of the study were fairly similar for treated plants of scarlet globemallow, but control plants had higher yields in 1973 than in 1972 (Table 8). All clipping treatments reduced yield even after a rest period, with clipping at rapid growth being the most severe. Herbage yield was less affected by a quiescence clipping in both years, but the differences between this treatment and the control was greater in 1973 than in 1972.

The effects of clipping treatments on carbohydrate reserve levels of scarlet globemallow were not great after a period of rest. In addition, the differences in carbohydrate reserve levels between the two years of study were small. All of the clipped plants made nearly complete recovery in both root and crown carbohydrate reserve levels after a period of rest (Table 8).

Blue grama:

Herbage yield and seedstalk length of defoliated blue grama plants did not fully recover even after a given period of rest (Table 9). Seedstalks were much shorter in 1972 than in 1973, however herbage yields were fairly similar in both years of the study.

A single defoliation at quiescence had the least effect on seedstalk length, but the seedstalk length was still below that of control plants. Defoliation at either early growth or near maturity appeared to be detrimental to seedstalk length of blue grama plants in both years.

All clipping treatments greatly lowered the herbage yield of defoliated blue grama below that of the control plants. Herbage yield was most affected by defoliation at near maturity in both years. Defoliation at quiescence resulted in the smallest depression of herbage yield among the clipping treatments.

Table 9. Average herbage yield, vigor, and carbohydrate reserve levels in roots and crowns of blue grama (*Bouteloua gracilis*) subjected to a single defoliation during various phenological stages (1970 through 1972). Measurements and collections were made in the fall of 1972 and 1973 after clipped plants had received a period of rest.

Phenological stage when defoliated	Seedstalk length (cm)		Dry wt. of above ground biomass (g/m^2)		Carbohydrate reserve levels (mg/g)			
					Roots		Crowns	
	1972	1973	1972	1973	1972	1973	1972	1973
Control	22.7	52.3	798	663	50.2	68.0	69.8	87.6
Quiescence	17.0	43.7	652	441	38.5	64.1	53.3	75.9
Early growth	14.0	31.0	375	437	37.4	65.5	53.4	79.1
Rapid growth	15.0	42.3	459	375	37.9	59.8	55.5	85.8
Near maturity	10.3	37.0	306	369	43.2	60.0	58.1	84.7

The carbohydrate reserve levels in both roots and crowns of clipped and unclipped blue grama plants were higher in 1973 than in 1972 (Table 9). However, the differences in reserve levels among clipped and unclipped plants were greater in 1972 than in 1973. The 1973 study showed defoliated plants to have made good recovery in carbohydrate reserve levels after a period of rest. Only minor differences in carbohydrate levels among clipping treatments were detected.

Western wheatgrass:

All clipping treatments reduced the vigor and herbage yield of western wheatgrass even after defoliated plants had received a period of rest (Table 10). Plant height was higher in 1973 than in 1972, but defoliated plants made less fall regrowth in 1973. Plants that were defoliated at either quiescence or early growth were taller than those that received a defoliation at rapid growth. Fall regrowth was only slightly affected by the clipping treatments during both years of the study, with quiescence defoliated plants showing slightly more fall regrowth than plants from the other clipping treatments.

Defoliated plants showed somewhat greater recovery in herbage yield in 1972 than in 1973. The results however showed that a quiescence defoliation was less detrimental to herbage yield recovery whereas defoliation at the rapid growth stage and the boot stage depressed the recovery of western wheatgrass herbage yield.

Defoliated plants of western wheatgrass showed good recovery in carbohydrate reserve levels of both storage organs during the rest period (Table 10). Carbohydrate reserve levels were generally higher in 1973 than in 1972 and defoliated plants showed more recovery in carbohydrate

Table 10. Average herbage yield, vigor and carbohydrate reserve levels in roots and crowns of western wheatgrass *(Agropyron smithii)* subjected to a single defoliation during various phenological stages (1970 through 1972). Measurements and collections were made in the fall of 1972 and 1973 after clipped plants had received a period of rest.

Phenological stage when defoliated	Vigor: Plant height (cm) 1972	Vigor: Plant height (cm) 1973	Vigor: Fall regrowth (cm) 1972	Vigor: Fall regrowth (cm) 1973	Dry wt. per shoot (g) 1972	Dry wt. per shoot (g) 1973	Carbohydrate reserve levels (mg/g): Roots 1972	Roots 1973	Crowns 1972	Crowns 1973
Control	26.7	35.7	10.3	9.3	0.29	0.64	157.1	131.7	125.3	118.3
Quiescence	23.3	26.0	8.7	5.0	0.30	0.44	117.0	160.6	109.4	109.5
Early growth	21.0	28.0	7.0	4.2	0.24	0.42	112.4	182.4	106.7	128.5
Rapid growth	18.7	26.3	7.7	4.0	0.19	0.42	124.8	142.6	122.5	133.2
Boot stage	17.0	28.3	8.7	4.3	0.21	0.35	124.6	151.6	125.0	96.4

reserve stores in 1973 than in 1972. There was little difference in carbohydrate reserve levels among plants from the various defoliation treatments. Rapid growth defoliations resulted in plants with the highest crown carbohydrate reserve levels among the clipping treatments.

2. Multiple defoliation experiment

Four species, fourwing saltbush, antelope bitterbrush, blue grama and scarlet globemallow were included in this portion of the study. Plants were subjected to three defoliations at three different phenological stages of development and were then given at least one or two years of rest after clippings. All species were clipped to remove 90% of the photosynthetically active tissue at each clipping.

Fourwing saltbush:

Live crown cover, herbage yield and carbohydrate reserve levels of clipped fourwing saltbush were still less than those of controls after at least one complete year of rest (Table 11). However, seedstalk length of multiple defoliated plants actually exceeded those of unclipped plants. After two years of rest, significant recovery in live crown cover and herbage yield was made, but decreases in seedstalk length and carbohydrate reserve levels in both tap roots and basal stems were noted. This may indicate that multiple defoliated plants were still not net producers of carbohydrates and were utilizing reserves to restore aboveground herbage production.

Antelope bitterbrush:

The effects of multipe clippings at quiescence, fruit developing and fall regrowth on antelope bitterbrush were still present even after one or two years of rest. This was evidenced in a reduction in live crown cover,

Table 11. Average differences (control-clipped) in herbage yield, vigor and carbohydrate reserve levels in tap roots and basal stems of fourwing saltbush *(Atriplex canescens)* subjected to multiple defoliations at three phenological stages during 1970 and 1971. Measurements and collections were made in the fall of 1972 and 1973 after plants had received at least one or two years of rest.

Length of rest period after being clipped at quiescence, rapid growth and seed shatter in 1970-1971	Vigor		Dry wt. of leaves and seeds per plant (g)	Carbohydrate reserve levels (mg/g)	
	Seedstalk length(cm)	Live crown cover (%)		Tap roots	Basal Stems
Given at least one year of rest and collected in Fall, 1972	-5.8[1]	70	157.0	0.6	9.8
Given at least two years of rest and collected in Fall, 1973	4.0	30	58.7	20.3	17.0

[1] Negative sign indicates that clipped plants exceeded those of control plants.

Table 12. Average differences (control-clipped) in herbage yield, vigor, and carbohydrate reserve levels in tap roots and basal stems of antelope bitterbrush *(Purshia tridentata)* subjected to multiple defoliations at three phenological stages during 1970 and 1971. Measurements and collections were made in the fall of 1972 and 1973 after plants had received at least one or two years of rest.

Length of rest period after being clipped at quiescence, fruit development and fall regrowth in 1970-1971	Vigor		Dry wt. of leaves per plant (g)	Carbohydrate reserve levels (mg/g)	
	Twig length (cm)	Live crown cover (%)		Tap root	Basal Stem
Given at least one year of rest and collected in Fall, 1972	- 3.4[1]	63.3	26.2	18.1	24.6
Given at least two years of rest and collected in Fall, 1973	- 0.6	50.0	40.4	- 0.9	30.1

[1] Negative sign indicates that clipped plants exceeded those of control plants.

herbage yield and basal stem carbohydrate reserve levels of clipped plants compared to unclipped plants (Table 12). However one or two years of rest were sufficient for the complete recovery of twig length. In fact, clipped bitterbrush plants had slightly longer twigs as compared with control plants after either one or two years of rest. Clipped plants had slightly more live crown cover after two years of rest than after one year of rest. However, greater herbage yield was obtained after one year of rest than after two years of rest. Two years of rest appeared to be sufficient for recovery of tap root carbohydrate reserve levels, but basal stem reserve levels were still suppressed.

Scarlet globemallow:

One or two years of rest was insufficient for the recovery of vigor and herbage yield of clipped scarlet globemallow plants (Table 13). There was little difference in the amount of fall regrowth or plant height of clipped plants after one or two years of rest. However, clipped plants had more herbage yield after one year of rest than after two years of rest. Carbohydrate reserve levels in roots and crowns of clipped plants were higher than reserve levels of control plants after either one or two years of rest. Clipped plants also had greater root carbohydrate reserve levels after two years of rest than after one year of rest, with reserve levels in the crowns showing the opposite trend. These results may suggest that clipped plants were not substiantially utilizing stored carbohydrate reserves for production of new growth as were control plants which produced more growth than the clipped plants.

Blue grama:

The results of the multiple defoliation study showed that one or two years of rest was insufficient for the recovery of clipped blue grama plants

Table 13. Average differences (control-clipped) in herbage yield, vigor, and carbohydrate reserve levels in roots and crowns of scarlet globemallow *(Sphaeralcea coccinea)* subjected to multiple defoliations at three phenological stages during 1970 and 1971. Measurements and collections were made in the fall of 1972 and 1973 after plants had received at least one or two years of rest.

Length of rest period after being clipped at quiescence, rapid growth and seed shatter in 1970 and 1971	Vigor		Dry wt. per shoot (g)	Carbohydrate reserve levels (mg/g)	
	Plant height (cm)	Fall regrowth (cm)		Roots	Crowns
Given at least one year of rest and collected in fall, 1972	3.8	0.4	0.27	- 22.2[1]	- 4.1
Given at least two years of rest and collected in fall, 1973	4.0	0.6	0.44	- 31.3	- 2.6

[1] Negative sign indicates that clipped plants exceeded those of control plants.

Table 14. Average differences (control-clipped) in herbage yield, vigor and carbohydrate reserve levels in roots and crowns of blue grama *(Bouteloua gracilis)* subjected to multiple defoliations at three phenological stages during 1970 and 1971. Measurements and collections were made in the fall of 1972 and 1973 after plants had received at least one or two years of rest.

Length of rest period after being clipped at quiescence, rapid growth and regrowth in 1970 and 1971	Seedstalk length(cm)	Dry wt. of aboveground biomass (g/m^2)[1]	Carbohydrate reserve levels (mg/g) Roots	Crowns
Given at least one year of rest and collected in fall, 1972	9.7	464.1	12.8	15.6
Given at least two years of rest and collected in fall, 1973	18.6	204.0	7.4	3.2

[1] Expressed on a basis of 100% basal cover.

(Table 14). Herbage yield, seedstalk length, and carbohydrate reserve levels of clipped plants were still significantly below those of control plants after either one or two years of rest.

Seedstalk length was greater after one year of rest than after two years of rest (Table 14). However, herbage yield after one year of rest was less than half that obtained after two years of rest.

Root and crown carbohydrate reserve levels of clipped blue grama plants were greater after two years of rest than after one year of rest (Table 14). However, the influence of the rest duration was more pronounced in crown carbohydrate reserve levels than in the root reserve levels. It was observed that crown carbohydrate reserve levels showed a significant recovery after two years of rest.

SUMMARY

The effects of forage utilization on herbage yield, vigor and carbohydrate reserve levels of several important range species were studied on the shortgrass prairie at the Pawnee site and on the intermountain shrubland type near Maybell, Colorado. Two experiments were conducted at both locations. In the first experiment the effects of multipe defoliations, at 90 percent and 60 percent foliage removal, were examined by measuring the welfare of three species. In the second experiment the recovery of some important range species subjected to either a single defoliation or multiple defoliations to remove 90 percent of photosynthetically active tissue at each clipping was examined after clipped plants were given a period of rest. Clipped plants were given at least one or two years of rest after clipping.

The effects of the previous clipping treatments were evaluated in the

fall of 1973 in the first experiment where plants had not received a rest period. Plants which had received at least two years of rest from multiple defoliations in the second experiment were also evaluated in the fall of 1972. Plants from the single defoliation treatments in the second experiment were evaluated in the fall of 1972, and the experiment was again repeated and evaluated in the fall of 1973. Clipped plants, therefore, received the same period of rest whether collected in the fall of 1972 or 1973.

The results from the first experiment showed that in general, heavy defoliation at 90 percent foliage removal was more detrimental to herbage yield, vigor and carbohydrate reserve levels of blue grama, fourwing saltbush, and western wheatgrass than defoliation at 60 percent intensity. Defoliation at quiescence and again at rapid growth was less detrimental to the vigor and herbage yield of blue grama and western wheatgrass than a similar defoliation intensity at other phenological stages of development. Herbage yield and vigor of fourwing saltbush was least affected by moderate clippings at quiescence and rapid growth or rapid growth and seedset. Heavy defoliations of fourwing saltbush was very detrimental to the welfare of the clipped plants, with clipping at quiescence and seedset being the most detrimental of all the clipping treatments studied.

Three multiple defoliations at quiescence, rapid growth and seedset reduced the herbage yield and vigor of western wheatgrass more than did two multiple defoliations. Western wheatgrass was the only species studied under three clipping treatments.

The effect of two clipping intensities on carbohydrate reserve levels in the first experiment were not consistant among species.

Carbohydrate reserve levels were usually less affected by clipping intensity as compared with results obtained for herbage yield and other measures of vigor. Clipping at either heavy or moderate intensities had little effect on root carbohydrate reserve levels of blue grama and western wheatgrass. However, moderate clipping of fourwing saltbush resulted in a higher basal stem carbohydrate reserve level as compared with heavy defoliation at the same phenological stage. Heavy defoliation of fourwing saltbush after seedset greatly reduced basal stem carbohydrate reserve levels.

In the second experiment, recovery of plants defoliated at one time and given at least a 14-month rest period varied among the species studied. The results of this experiment showed that, in general, a 14-month rest period was insufficient for the complete recovery of herbage yield and vigor of clipped plants. All of the species included in this study (blue grama, western wheatgrass, fourwing saltbush, antelope bitterbrush, fringed sagewort, scarlet globemallow and little rabbitbrush) still had lower herbage yields after a period of rest as compared with unclipped plants. The effects of previous clipping treatments on carbohydrate reserve levels of little rabbitbrush, blue grama, western wheatgrass and scarlet globemallow were only slight after at least one year of rest.

In general, herbage yield, vigor and carbohydrate reserve levels of plants that had received multiple defoliations and were then given at least one or two years of rest (except carbohydrate reserve levels of scarlet globemallow) were still significantly lower than the unclipped plants. Herbage yield was greatly depressed by multiple defoliations, with little recovery occurring after a period of rest. Scarlet globemallow

was the only species that showed complete recovery of carbohydrate reserve levels in both roots and crowns when given one or two years of rest.